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ABSTRACT

This study examined the differential effects of two instructional strategies on the acquisition, maintenance, and generalization of mathematical word problem solving by students with learning disabilities: an explicit schema-based problem solving strategy (SBI) and a traditional general heuristic instructional strategy (TI). Twenty-two middle school students with learning disabilities and problems in mathematics were randomly assigned to one of the two treatment conditions. The two instructional strategies were compared using a repeated measure with control group design. Results indicated that the SBI group significantly outperformed the TI group on the posttest, maintenance test (1 to 2 weeks later), and follow-up test (3 weeks to 3 months later). The SBI group also significantly outperformed the TI group in solving transfer (i.e., structurally similar but more complex) problems following the assigned strategy instruction. Additionally, the performance of the SBI group on the posttest, maintenance, and follow-up tests surpassed a normative sample of 6th graders. Implications for practice are discussed. (Contains 20 references.) (Author/DB)

A Comparison of Two Instructional Approaches on Mathematical Word Problem Solving by Students with Learning Problems

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Abstract

This study examined the differential effects of two instructional strategies, an explicit schema-based problem solving strategy (SBI) and a traditional general heuristic instructional strategy (TI), on the acquisition, maintenance, and generalization of mathematical word problem solving. Twenty-two middle school students with learning disabilities and problems in mathematics were randomly assigned to each of the two treatment conditions (SBI and TI). A repeated measure with control group design was employed to compare the effects of the two instructional strategies. Results indicated that the SBI group significantly outperformed the TI group on the posttest, maintenance test (1 to 2 weeks later), and follow-up test (3 weeks to 3 months later). The SBI group also significantly outperformed the TI group in solving transfer (i.e., structurally similar but more complex) problems following the assigned strategy instruction. In addition, the performance of the SBI group on the posttest, maintenance, and follow-up tests surpassed a normative sample of 6^{th} graders. Implications for practice are discussed.

A Comparison of Two Instructional Approaches on Mathematical Word Problem Solving by Students with Learning Problems

Currently, a growing number of students with disabilities are being served in the general education classrooms (Cawley, Parmar, Foley, Salmon, & Roy, 2001). With the new provisions of the amendment to the Individuals with Disabilities Act (IDEA), these students are held accountable to the same high academic standards (e.g., National Council of Teachers of Mathematics [NCTM], 2000) required of all students. However, students with learning disabilities manifest serious deficits in mathematics, especially problem solving (Carnine, Jones, & Dixon, 1994; Cawley & Miller, 1989; Cawley, Parmar, Foley, Salmon, & Roy, 2001; Parmar, Cawley, & Frazita, 1996). Specifically, these students perform at significantly lower levels than students without disabilities on all problem types (Cawley et al., 2001; Parmar, Cawley, & Frazita, 1996). Clearly, effective strategies are needed to allow students with disabilities access higher order thinking in mathematics. This would entail strategies that emphasize the NCTM process standards of being able to problem solve, reason, communicate, connect, and represent mathematics.

Recent reviews provide empirical support for problem solving instruction that emphasizes conceptual understanding (Xin & Jitendra, 1999). Schema-based instruction, a representational technique, is one such strategy that emphasizes conceptual understanding of the problem structure (i.e., problem schemata). Schema acquisition allows the learner to accurately solve a group of seemingly different but structurally similar problems. However, traditional instructional models emphasize either a general heuristic procedure (i.e., read to understand, develop a plan, carry out the plan, and look back to check) or use of the key word method (e.g., "altogether" implies use of addition, whereas "left" implies subtraction). Unfortunately, neither of these procedures considers problem schema acquisition, which is a prerequisite to effective problem solving.

Emerging research on the effects of schema-based instruction to solve arithmetic word problems is encouraging. Schema-based strategy instruction is known to benefit both special education students (e.g., Jitendra, Hoff, & Beck, 1999) and students at risk for math failure (e.g., Jitendra, Griffin, McGoey, Gardill, Bhat, & Riley, 1998). In addition, the effects of semantic representation training in facilitating accurate problem solving have been demonstrated with college students with and without disabilities (Lewis, 1989; Zawaiza & Gerber, 1993).

Most previous research studies that examined the effectiveness of schema-based instruction to teach problem representation and solution are limited to addition and subtraction (i.e., change, combine, and additive compare) word problems. However, students with learning problems have more trouble solving multiplication and division word problems than addition and subtraction problems (Parmar, Cawley, & Frazita, 1996; Van de Walle, 1998). On the other hand, the semantic representation strategies investigated in the Lewis (1989) as well as the Zawaizer and Gerber (1993) studies only apply to comparison problems. Both these studies did not emphasize key concepts pertinent to the compare problem schemata such as "the compared" and "the referent." Furthermore, the rules that were used for students to figure out the operation (e.g., if the unknown quantity is to the right of the given quantity on the number line, then addition or multiplication should be applied) could not be directly applied in solving multiplication/division compare problems when the relational statement involved a fraction (e.g., 2/3).

Therefore, the purpose of the present investigation was to extend the current schema-based instructional research on addition and subtraction word problem solving to multiplication and division word problems for students with learning disabilities. Specifically, the study was designed to (a) evaluate and compare the effectiveness of two instructional approaches in teaching multiplication and division word problems to middle school students with learning disabilities; (b) examine the maintenance of students' word problem solving performance, (c) investigate students' generalization of learned problem solving strategies to different but structurally similar problems; and (d) compare the word problem solving performance of students with learning disabilities with that of normally achieving nondisabled peers.

Method

Participants and Settings

Participants in this study included middle school students with learning problems, because multiplication and division problems investigated in this study are those that typically occur in middle school level mathematics curricula. Specifically, students who satisfied the following criteria were selected to participate in this study. That is, students (a) were diagnosed with learning disabilities according to the Pennsylvania State Standards and district eligibility criteria, and/or were identified by their teachers as having substantial problems in mathematics word problem solving; and (b) scored at 70% or lower on the word problem solving criterion test (i.e., pretest) involving multiplication and division word problems.

A total of 22 middle students with learning problems who met the above criteria participated in the study. To determine sample size, a power analysis using an alpha level of .05 and an effect size of .76 based on existing schema-based instruction research studies (e.g., Jitendra et al., 1998) was conducted. The analysis indicated that, with a repeated measure ANOVA (2x4), a minimum of 10 participants in each group is sufficient to obtain a power of .90 (N=10, power= .918).

Students in this study were randomly assigned to one of two groups (schema-based instruction and traditional heuristic instruction). In addition, as a normative reference, eight 6th graders who attended the same school as participants in this study completed the pretest, posttest, maintenance, and follow-up tests only. The selection of this normative reference group was volunteer-based. Due to the participating school's specific circumstances, only 6th graders were available and therefore served as the normative reference group. This group of 6th graders did not receive any intervention, but served as a reference group for evaluating typical word problem solving performance.

The present study was conducted in an urban public middle school in northeastern Pennsylvania. More specifically, eight of the participants (i.e., 4 in each comparison group) received their assigned interventions in an after-school program and 14 students (7 in each of comparison groups) received the intervention in a summer school program. Both the after-school and summer school programs were federally funded programs. Table 1 presents demographic information about participants' gender, grade, age, ethnicity, special education classification, IQ levels, and standardized achievement scores in math and reading for the two comparison groups.

<Table 1 About Here>

During the after-school program, all instruction and testing took place in two classrooms, one for the schema group and one for the traditional group. Two volunteer graduate students in special education and school psychology served as the instructors for both groups. During the summer school program, all instruction and testing took place in the morning in two university classrooms. Two school district teachers were hired for delivering the instruction. One teacher had five years' teaching experience, and the other was a first year teacher. However, this first year teacher had been working as a teacher substitute for about one year before being hired as a teacher. During both after-school and summer school programs, a teacher assistant from the participating school was assigned to the instructors to help with both classes.

Measures

The first author developed all the measures and materials used in this study. The dependent variables included measures of students' math word problem solving performance in solving target and transfer problems. Target problems were one-step multiplicative compare and proportion word problems similar to ones used during the strategy instruction. Transfer problems were multiplicative compare and proportion word problems derived from commercially published mathematics textbooks (e.g., Silver Burdett Ginn, Harcourt Brace Jovanovich, Houghton Mifflin Company) and standardized achievement tests (e.g., Woodcock-Johnson Tests of Achievement).

Target problems were used in developing word problem solving tests for assessing students' acquisition and maintenance of word problem solving skills. Four parallel test forms, each containing 16 one-step multiplication and division word problems (i.e., multiplicative compare and proportion) were developed for use as the pretest, posttest, maintenance test, and follow-up test. The 16 target problems were designed to include each of several variations of *multiplicative compare* and *proportion* problems that were similar to the problems used during the intervention. *Multiplicative compare* problems varied in terms of the position of the unknown in the problems. That is, the unknown quantity could be the compared, referent, or the scalar function (the quantity that indicates the multiple or partial relation when comparing the two quantities). The *proportion* problems ranged from one in which the unit value was unknown to the ones in which the quantity of either one of the two dimensions was unknown (see Table 2).

<Table 2 About Here >

The only difference between the four parallel test forms was the problem's story character(s) and the numerical values appearing in the problem. The reliability and equivalence of the four parallel test forms were established by testing a group of 6th grade students from the same school as the participants in the study. The parallel form reliability of the four test forms was calculated using the Pearson Product-Moment Correlation Coefficient formula (Glass & Hopkins, 1984). Reliabilities ranged from .79 to .93, with an average of .84.

In addition, a generalization test containing 10 transfer problems was developed to assess students' transfer of learned skills to structurally similar but more complex problems. This test included three multiplicative compare and seven proportion problems (one multi-step problem and three problems involving irrelevant information).

<u>Procedures</u>

Both experimental groups (i.e., schema-based instruction vs. traditional instruction) completed: (a) the pretest and generalization test prior to their respective word problem solving treatment instruction, (b) the posttest and the generalization test immediately following the treatment instruction, (c) the maintenance test with a one to two-week lapse after the termination of the treatment instruction, and (d) the follow-up test with a lapse time ranging from three weeks to about three months. Administering the generalization test before and after the intervention examined students' ability to transfer their learned strategies to more complex problems and investigated the influence of two types of instructional strategies on students' performance.

In addition, both groups completed part one of the survey questionnaire before and after the implementation of the instruction and completed part II of the survey questionnaire following the treatment instruction only. The purpose of administering part one of the survey questionnaire before and after the strategy instruction was to explore any interaction between the strategy instruction and possible change in students' self-perception including affective responses (Montague, 1997b). To allow for a normative comparison, the normative reference group completed the pretest, posttest, maintenance test, and follow-up test at about the same time as the experimental groups.

Testing and Scoring Procedures

Students took the test in small groups in a quiet room. They were instructed to read the problem and try their best to solve the problem. Also, students were encouraged to show all of their work in the space available on the test sheet. Students were assisted if they had difficulty reading words on the test. They were provided with sufficient time to complete the test. No feedback was given regarding the accuracy of their solution or work during all testing. For the self-perception survey, students were encouraged to give their honest responses to each item on the questionnaire.

The scoring of word problem solving performance tests was in accordance with the following scoring system. That is, one whole point was awarded for each problem if the (a) math sentence or equation set-up was correct, (b) computation based on the set-up was correct, and (c) answer written on the answer line was correct; or simply the answer to the problem written on the answer line was correct if no problem solving process was shown. Two third of a point was awarded if both (a) and (b) were satisfied, but the answer to the problem was wrong. One half point was given if only (a) was met. In the latter case, the student may set up the math sentence or equation correct (or choose the right operation), but make errors in computing (i.e., execution of the arithmetic). Responses were scored as zero if none of the above conditions were met.

Instructional Procedures

During the intervention, the experimental group received schema-based instruction, whereas the comparison group received the traditional general heuristic instruction. All instruction was scripted. Instructional scripts were piloted prior to being used in the study. The first author trained the instructors in two one-hour sessions using the instructional scripts. During the training, the investigator modeled the strategies using several examples and had the instructors demonstrate teaching word problem solving using the two different strategies. All questions and concerns regarding the strategies were clarified during training. Instructors were alternated across treatment conditions to control for teacher effects.

Both the schema and the traditional instruction groups received their assigned instruction three to four times a week, with each session lasting about an hour. The schema-based instruction group received 12 sessions of instruction with four sessions of instruction in solving each word problem type (i.e., multiplicative compare and proportion problems) and four sessions of instruction in solving mixed word problem types. The traditional instruction group also received 12 sessions of instruction. However, this group worked on solving a mixed group of word problems during each session, because they were not provided with direct instruction in recognizing different word problem types. In addition, both groups of students were instructed to solve the same number of problems derived from the same problem pool.

Schema-Based Instruction (SBI) Condition

The schema-based problem solving strategies developed for this study is based on the work of Marshall (1995) and Nesher (1992). Instruction for the SBI group occurred in two phases: problem schemata instruction and problem solving instruction. Below is a general description of each instructional phase for each of two problem types (Multiplicative compare and proportion) investigated in this study.

Multiplicative compare problem In teaching *multiplicative compare* problem schema, the following salient features were highlighted. That is, there is always a (a) referent set, including its identity and its corresponding quantity; (b) compared set, including its identity and corresponding quantity; and (c) relational statement that relates the compared set to the referent set. In short, the *multiplicative compare* problem describes one object to be the referent and expresses the other as a part or multiple of it. The following story situation will be used to illustrate the problem schema instruction process: "Vito earned $12 from shoveling snow over the weekend. He earned 1/3 as much as his friend Guy did. Guy earned $36 from shoveling the snow." First, students were taught to identity the problem type. In this story situation, because the $ Vito earned was compared to the $ that Guy earned, it was deemed to be a comparison problem situation. Furthermore, the comparison indicated a multiplicative relationship (i.e., multiple or part) rather than a "more or less" situation. As such, it represents a *multiplicative* compare problem situation rather than an *additive* compare situation. Students were provided with a prompt sheet that contained the definition of the problem type and the five steps to guide them through the problem solving process

Step 1 required students to find and underline the relational statement in the problem. In the above sample story situation, the relational statement would be, "He earned 1/3 as much as his friend Guy did." Step 2 had students find the referent and compared and write them in the diagram. Students were taught that the second subject/object (i.e., "Guy") in the relational statement is the referent, and the first subject/object (i.e., "Vito") in the relational statement is the compared. Students were also taught that the second subject/object typically follows the phrase,

"… as many … as …" or "… as much … as …", and the first subject/object is the one before the second subject/object. Step 3 asked students to find corresponding information that related to the compared, referent, and compare relation and map them onto the diagram. Students were instructed to read the story again and find the information about the compared (i.e., the $ Vito earned: $12) and the referent (the $ Guy earned: $36) and to write the quantities with the labels onto the diagram. Students were also taught to find information about the relation (i.e., 1/3) in the relational statement and write it in the oval in the diagram (see Figure 1).

<Figure 1 About Here>

During problem schema mapping, students had to map the identities with their corresponding quantities onto the right position in the diagram. After completing the mapping, the teacher summarized the diagram. Then students were taught to check the accuracy of their representations by transforming the diagram into a math equation. That is, 12/36 = 1/3. If the equation was not established (e.g., 36/12 ≠ 1/3) in students' representations, they were instructed to check on each part of their mapping and correct their representations by reviewing the definitions of each component in the multiplicative compare problem schema (i.e., the referent, compared, and relation). In addition, the instructor emphasized the rationale for learning the problem schema. That is, the schematic diagram used to represent the problem/story situation reflected the mathematical structure of the problem. The completed diagram served to help students determine the choice of operations or set up the math sentence/equation.

In the problem solving instruction phase, students were presented with real problems rather than story situations. Using the earlier example, the problem situation might entail one unknown quantity. For instance, "Vito earned $12 from shoveling snow over the weekend. He earned 1/3 as much as his friend Guy did. How much did Guy earn from shoveling the snow?"

To solve this problem, students were instructed to first represent the problem using the corresponding schematic diagram as they did in the problem schema instruction phase. The only difference was that students were taught to use "?" to flag the unknown quantity in the diagram (i.e., the $ Guy earned).

After completing the schematic representation, the rest of the problem solving steps were as follows. Step 4 required students to transform the diagram into a math equation and solve for the unknown. For step 5, students had to write a complete answer on the answer line and check their answer. To solve the above sample problem, students were taught to transform the diagram representation directly into the following math sentence, "12/? = 1/3." To answer the problem, students learned to use cross-product method to solve for the unknown (i.e., "? = 12 x 3 = 36"). After students solved the problem, the last step was to check the answer. They were taught to replace the "?" with their answer in the diagram and to check the accuracy of both the representation and computation. Students were reminded to always use reasoning and critical thinking when mapping information onto the diagram. The representation was based on their conceptual understanding of the problem situation.

Proportion problem. In teaching the *proportion* problem schema, the following salient features were emphasized: (a) the *proportion* problem describes an association (i.e., a ratio) between two things; (b) there are two pairs of association between two things that involve four quantities; and (c) the numerical association (i.e., the ratio) between two things is constant across two pairs. In this type of problem, there is an "if…then" relationship. That is, one pair of association is the IF statement, and the other is the THEN statement. Typically, the "if" declares a per-unit value (or unit ratio) in one pair, and the "then" describes the variation (enlargement or decrement) of the two quantities in the second pair with the unit ratio unchanged (e.g., if one shelf holds 12 books, then 4 shelves will hold 48 books). In short, this type of problem describes a constant ratio across two pairs of association between two things. For example, "A recipe for chocolate cupcakes uses 3 eggs to make 20 cupcakes. If you want to make 80 cupcakes, you need 12 eggs." First, students were taught to identify the problem type. Because the problem was about the ratio between eggs and cupcakes, and involved two pairs of varied associations with the unit ratio unchanged, therefore it was deemed to be a proportion story situation. As in teaching multiplicative compare problems, students were provided with a prompt sheet that contained the definition of the problem type and the four steps to guide them through the problem solving process.

For step 1, students had to identify the two things (or dimensions) that form a specific association (ratio) in the story situation, and define one as the subject and the other as the object. In above sample story situation, "eggs" and "cupcakes" were the two things that formed a ratio. Students were instructed to identify one (e.g., "eggs") as the subject and the other (i.e., "cupcakes") as the object, and write them in the diagram under the "subject" and "object" dimensions, respectively (see Figure 2). Step 2 asked students to find out the two pairs of numerical association (involving four quantities) and map them onto the diagram. Instruction in representation and mapping emphasized the correct alignment of the two dimensions (i.e., the "eggs" column and the "cupcakes" column) with their corresponding quantities. That is, the first pair is "3 eggs" for "20 cupcakes"; and the second pair is "12 eggs" for "80 cupcakes" rather than "80 cupcakes" for "12 eggs." In other words, the labels (# of eggs) for the subject (eggs) column must be the same; and the labels (# of cupcakes) for the object (cupcakes) column must be the same. Students were reminded to continue to use reasoning and critical thinking when mapping information onto the diagram. As with the multiplicative compare problems, students were instructed to check on their representation by transforming the diagram into a mathematical equation (i.e., 3/12 = 20/80). If the equation was not established in their representation, students were instructed to check on their mapping (i.e., whether or not the two pairs of associations were correctly aligned) and correct their representation. The teacher also pointed out that, because the schematic diagram they were learning reflected the structure of the proportion problem; they could use it to help solve the problem.

<Figure 2 About Here>

In the problem solving instruction phase, problems with an unknown value were presented to students. Students were instructed to first represent the problem using the schematic diagram as they did in the problem schema instruction phase. The only difference was that they used "?" to flag the unknown. After completing the representation, students had to follow Step 3 to transform the diagram into a math equation and solve for the unknown. Students were taught that because the *proportion* problem schema entails a constant ratio across two pairs of association, the equation is set up by placing an equal sign in between the two ratios in the diagram to indicate they are equivalent ratios. For this problem, "A recipe for chocolate cupcakes uses 3 eggs to make 20 cupcakes. If you want to make 80 cupcakes, how many eggs will you need?", the math equation from the diagram representation would be as follows: 3 / ? = 12 / 80. To solve for the missing value in the equation, students were taught to use the cross-product method to find the unknown in the equation. That is, ? = (3 x 80) ÷20 = 12. The last step, Step 4, was to write a complete answer on the answer line and check. Students were not only taught to replace the question mark with the answer to check the accuracy of the computation; but also instructed to use reasoning and critical thinking to check whether they correctly paired up the quantities of the subject and object (i.e., "3 eggs" for "20 cupcakes", and "? eggs" for "80 cupcakes").

Across the two phases of schema-based instruction, higher order thinking, reasoning, and connecting to students' previous knowledge were also emphasized. For instance, when mixed word problems were presented, the sameness and difference between the *multiplicative compare* and *proportion* problems were discussed in order for students to differentiate one type of problem from another. For example, students were taught that if the problem was about a multiplicative comparison between two quantities, then it referred to a *multiplicative compare* problem. If the problem was about a constant ratio across two pairs of association, then it indicated a *proportion* problem. Initially, one type of word problem with the corresponding schema diagram appeared on student worksheets. After students learned how to solve both types of problems, mixed word problems (with both diagrams provided for each problem on the worksheet) were presented.

<u>Traditional General Heuristic Instruction (TI) Condition</u>

Instruction for the TI group was derived from the strategy typically employed in commercially published mathematics textbooks (e.g., Harcourt Brace Jovanovich, Mathematics Plus, 1992). A four-step general heuristic problem solving was used in this study. The four steps were (a) read to understand, (b) develop a plan, (c) solve, and (d) look back. During the teacher's modeling of the strategy, a Problem-Solving Think-Along transparency was used to guide discussion of the four-step problem solving procedure. Students were instructed to "think along" during the problem solving process. For example, for the first step, <u>Understand</u>, the teacher would ask students "What are you asked to find out in the problem?" "What information is given in the problem?" Students were encouraged to retell the problem in their own words and list the information given. For the second step, Plan, the teacher asked students questions such as, "What problem-solving strategies could you use?" On the transparency or the Think-Along work sheet, several strategies (i.e., *Draw a picture, make a table, make a model, write a math sentence, act it out*) were listed for "Plan" Step. Students could choose one of several strategies if they could not come up with their own. Students were encouraged to list one or more problem-solving strategies that they could use and predict their answer. For the third step, Solve, students were required to show how they solved the problem, and write their answer in a complete sentence. For the last step, Look back, the teacher asked students to justify whether their answer was reasonable and to indicate whether they could have solved the problem in another way.

During the traditional heuristic instruction, student worksheets included the Think-Along four steps for each modeling and guided practice problems. Students were encouraged to work the problem by following each listed step. For independent practice, a separate Think-Along sheet containing the four steps was provided to help students solve problems.

Both Conditions

Across both SBI and TI conditions, the teacher first modeled the assigned strategy with multiple examples. Explicit instruction was followed by teacher-guided student practice. Then, student independent work followed. Corrective feedback and additional modeling were provided, as needed. It should be noted that during both groups' instruction and testing in this study, students were allowed to use calculators to help them figure out the unknown as needed, because computation skills were not the focus of this study.

Treatment Fidelity

Teaching scripts were used to guide the strategy teaching for both the SBI and TI conditions during the intervention. In addition, for each strategy, a checklist that contained the instructional steps was developed to assess the instructor's adherence to the assigned strategy. The adherence of the instructor's teaching to the assigned instructional strategy was judged on the presence or absence of the features listed on the fidelity checklist.

Interrater Reliability

A graduate student who was blind to the purpose of the study scored all tests in this study using an answer key and also scored the survey questionnaire. To assess reliability of scoring, 30% of the tests and survey questionnaires were rescored by the first author. Interrater reliability was computed by dividing the number of agreements by the number of agreements and disagreements and multiplying by 100.

Results

Reliability

Results of interrater agreement for scoring all word problems solving tests and survey questionnaires were 100% across the two independent raters. Regarding treatment fidelity, about 20% of the after-school program's lessons (i.e., 20% of the SBI lessons and 20% of TI lessons) and about 42% of the summer school program lessons (i.e., 43% of the SBI lessons and 40% of the TI lessons) were observed by an independent rater using the procedure treatment fidelity checklist. Combining both the after-school and the summer programs, about 32% of the SBI lessons and 30% of the TI lessons were observed. The adherence of the instructor's teaching to the assigned instructional strategy ranged from 76% to 100%, with an average of 94% for the SBI group and 100% for the TI group. Most commonly, the instructor failed to define the specific problem schemata at the beginning of the lesson, or failed to give immediate feedback and correct students' error through modeling the correct response during the lesson. In this study, the instructors were given feedback if they missed any component listed in the procedure fidelity checklist. In addition, suggestions for improvement during the next lesson were provided.

Pretreatment Group Equivalency

Pretreatment group equivalency was tested by conducting a one-way analysis of variance (ANOVA) for group (SBI vs. TI) on students' word problem solving pretest performance. Specifically, students' pretreatment performance on target problems was 25.2% correct for the SBI group and 29.9% correct for the TI group. The result of an analysis of variance (ANOVA) indicated that there were no statistically significant differences between the two groups (F (1, 20) = .24, p = .63). Students' pretreatment performance on transfer problems was 25.5% correct for the SBI group and 35% correct for the TI group. Again, an analysis of variance showed no significant differences between the two groups (F (1, 20) = .74, p = .40). In short, the above analysis indicated that the two group students' pretreatment performance on word problem solving were equivalent.

Acquisition and Maintenance Effects of Word Problem Solving Instruction

A 2 (Group: SBI vs. TI) x 4 (Time of testing: pretest, posttest, maintenance test, and follow-up test) repeated measures ANOVA was performed to assess the effectiveness of two instructional strategies (i.e., schema vs. traditional instruction) on students' word problem solving performance. Results indicated that there was a significant main effect for group (F (1, 17) = 14.906, p = .001) and a significant main effect for time of testing (F (3, 15) = 33.276, p= .000). In addition, results indicated a statistically significant interaction between Group and Time of Testing (F (3, 15) = 9.507, p = .001). That is, the two comparison groups' performance over four times of testing showed different patterns of change (see Figure 3). In other words, the two treatment conditions had differential effects on the students' word problem solving performance. As shown in Figure 3, the two groups started at about the same level of performance during the pretest. However, after the assigned instruction, the SBI group outperformed the TI group substantially, although both groups appeared to improve their performance from pretest to posttest. During the maintenance and follow-up tests, the SBI group better maintained the improved posttest performance than the TI group. In short, Figure 3 showed that the rate of group mean increase from pretreatment to posttreatment for the SBI group was significantly greater than that for the TI group.

<Figure 3 About Here>

To further explore the differential effects of the two instructional strategies, a one-way ANOVA for group (SBI vs. TI) on students' posttest performance was conducted. The results indicated that there was a statistically significant difference between the two groups after receiving their assigned treatment instruction (F (1, 20) = 15.747, p = .001), favoring the SBI group. Specifically, the mean posttest score for the SBI and the TI groups was 79.41% (SD = 13.92) and 47.55 % (SD = 22.70) (see Table 3). It should be noted that there was no statistically significant difference between the two groups before the intervention, although the TI group mean was slightly higher than the SBI group mean (see Table 3). However, after the assigned strategy instruction, the SBI group mean was significantly higher than the TI group. As shown in Table 3, the two groups' performance change from pretreatment to posttreatment is marked. That is, the sign of the effect size changed from negative prior to the treatment to positive following the treatment, indicating a favorable effect for the SBI group after receiving the schema-based instruction. Although both groups performance improved from pretest to posttest, the mean increase in score for the SBI group (54.22%) was significantly greater than the mean increase in score for the TI group (17.70%) (see Table 3).

<Table 3 About Here>

To examine the maintenance effects of strategy instruction, post hoc Paired Samples Tests were conducted following the repeated measures ANOVA. Results showed that there was no significant performance change from posttest to maintenance test (t (19) = - 0.458, p = .652) for both groups. Also, no significant performance change was found from maintenance test to the follow-up test (t (18) = - 0.381, p = .708) for both groups. These findings indicate that students in both groups maintained their word problem solving performance following the posttest (see Figure 3).

Transfer Effect of Word Problem Solving Instruction

A repeated measures ANOVA (2[group] x 2[time]) was conducted to examine how the performance of the two groups (i.e., SBI vs. TI) on the generalization test changed over time of testing (i.e., pretreatment and posttreatment). Results indicated a main effect on time of testing (F (1, 19) = 18.465, p = .000). More importantly, the results showed a statistically significant interaction between treatment group and time of testing (F (1, 19) = 8.579, p = .009). That is, the two comparison groups' performance in solving transfer problems over time of testing showed different patterns of change (see Figure 4). In other words, the two treatment conditions had differential effects on the students' performance in solving transfer problems. As shown in Figure 4, the SBI group started with a slightly lower group mean than the TI group during the pretreatment test. However, after the assigned instruction, the SBI group surpassed the TI group during the posttreatment test. That is, the rate of group mean increase from pretreatment to posttreatment for the SBI group was significantly greater than that for the TI group.

<Figure 4 About Here>

Table 4 presents the descriptive statistics of the two groups' performance before and after their assigned strategy instruction. As shown in Table 4, the TI group started with a slightly higher group mean than the SBI group on the generalization test (TI M = 35.00%, SBI M = 25.45%), although there is no statistically significant difference between two groups. As such, a negative effect size (ES = - 0. 37) was obtained indicating a favorable effect for the TI group before the intervention. However, after the assigned strategy instruction, the SBI group mean increased to 62.43% and the TI group mean increased to 45.5%, resulting in a positive effect size favoring the SBI group. In short, these results indicated that although both groups seemed to improve their performance on the generalization test from pretreatment to posttreatment, the mean increase in score for the SBI group (38.0%) was significantly greater than the mean increase in score for the TI group (10.5%) (see Table 4).

<Table 4 About Here>

Normative Comparison

Figure 5 presents the results for the three groups' (SBI, TI, and normative reference) performance on target problems across time of testing. A descriptive analysis of the three group's performance in solving target word problems indicated that before the treatment, the SBI group (M = 25% correct, SD = 24) and the TI group (M = 30%, SD = 21) scored lower than the normative reference group of students without disabilities (M = 54%, SD =25) on the pretest. However, after instruction, the performance of the SBI group increased to 79% correct (SD = 14) and the TI group increased to 48% correct (SD = 23) on the posttest. That is, only the SBI group outperformed the normative reference group (M = 51%, SD = 25) following the schema-based instruction. On the maintenance test and follow-up tests, the SBI group scored 87% (SD = 15) and 92% (SD = 14), respectively; whereas the TI group scored 45% (SD = 18) and 46% (SD =19), respectively. Again, only the SBI group surpassed the normative reference group on the maintenance test (M = 60%, SD = 25) and follow-up test (M = 54%, SD = 23) (see Figure 5).

<Figure 5 About Here>

Discussion

Effect of SBI vs. TI on Students' Word Problem Solving Performance

This study compared the differential effects of schema-based instruction (SBI) and traditional heuristic instruction (TI) in teaching middle school students with learning disabilities to solve arithmetic multiplication and division problems (i.e., multiplicative compare and proportion). Results indicated that students in the SBI group significantly outperformed students in the TI group on measures of acquisition, maintenance (1 week to 3 months after the termination of the instruction), and generalization. The effect sizes ranged from .89 to 2.72. The results of this study supported the effectiveness of schema-based instruction in teaching word problem solving to students with learning disabilities (e.g., Jitendra and Hoff, 1996; Jitendra et al., 1998; Zawaiza & Gerber, 1993). In addition, this study extends previous schema-based instruction research in solving addition and subtraction word problems (e.g., Jitendra et al. 1998). The results of this study suggested that schema-based instruction is more effective than the traditional general heuristic instruction in teaching middle school students with learning difficulties to solve multiplication and division word problems (specifically, multiplicative compare and proportion problems).

On the measure of acquisition, although both groups' performance improved from pretest to posttest, the mean increase in score for the SBI group (54.22%) was significantly greater than the mean increase in score for the TI group (17.70%). The effect size obtained was 1.69. This effect size is much larger than the effect size (0.65) reported in the Jitendra et al. (1998) study. Specifically, in the Jitendra et al. (1998) study, elementary students with mild disabilities or at risk for mathematics failure learned to use schema diagrams to represent and solve addition and subtraction problems (i.e., change, group, and compare). After students represented the problem using schema diagrams, they needed to figure out which part in the diagram is the "total" or "whole", and apply a rule (i.e., "when the total [whole] is not know, we add to find the total; when the total is know, we subtract to find the other [part] amount." p.351) to decide whether to add or subtract to solve the problem. It might be the case that the schema diagrams for multiplication and division problems (i.e., multiplicative compare and proportion) in this study made a straightforward link between the problem schema representation and its solution, which expands upon the work of Marshall (1995) to meet the needs of individuals with learning problems. As such, errors were minimized once students correctly represented the problem in the diagram.

On the measure of maintenance effects, results indicated that students in the SBI group sustained their increased performance on the maintenance and follow-up tests (87% and 92%, respectively) when compared to the TI group (45% and 46%). The effect sizes obtained were 2.53 on the maintenance test (1 to 2 weeks later) and 2.72 on the follow-up test (3 weeks to 3 months later). Again, these effect sizes were lager than the one reported in the Jitendra et al. (1998) study (ES = 0.88 on a 1-week delayed posttest). In addition to the possible contributing factor described before, that is, the specific schema diagrams used in this study, the following observation should be noted. In this study, the schema group lost two participants during the maintenance and follow-up tests. In contrast, only one participant in the TI group missed the follow-up test. This difference in participants' attrition might partially contribute to the increase in score from the posttest to maintenance and follow-up tests in the schema group. Nevertheless, this study extends pervious research (e.g., Jitendra et al., 1999; Jitendra et al., 1998; Jitendra & Hoff, 1996) in that the follow-up test was administered up to three months after the instruction and the SBI group's better performance than the TI group was sustained.

One condition in this study should also be noticed when generalizing the results of this study. That is, before the maintenance and follow-up tests, both groups were reminded about the assigned strategy and asked to use it to solve problems on the tests. This might explain the boost in students' performance on the follow-up tests for both groups in this study. However, the greater effect of the schema-based instruction when compared to the traditional instruction in this study is marked.

Of special interest is the finding that the performance of the SBI group (79%, 87%, 92% on posttest, maintenance test, and follow-up test, respectively) surpassed the normative reference group (51%, 60%, 54%) after the strategy instruction, while the TI group (47%, 45%, 46%) approached the normative group. Previous research indicates that "when IQ and reading are controlled, 'true' math deficits are specific to mathematical concepts and problem types." (Zentall & Ferkis, 1993, p. 6). The emphasis of schema-based instruction in teaching conceptual understanding of the mathematical structure of specific problem types might have contributed to the substantial improvement of students' performance in the SBI group in this study.

In addition, it may be the case that the schematic diagram served as an external visual aid to help students organize information given in the problem. Given that students with learning difficulties often evidence cognitive disadvantage in attention, organization skills, and working memory (Gonzales & Espinel, 1999, Zentall & Ferkis, 1993) and consequently experience difficulties in rearranging information mentally (Marshall, 1995; Lewis & Mayer, 1987; Lewis, 1989), the schemata diagrams were useful aids to students in this study. That is, they helped students organize the information given in the problem and further guide them through the problem solving process, including correctly setting up the math sentence/equation to accurately solve the problem. The results of this study are consistent with previous research in that students with learning difficulties "did better under structured instruction, which appeared to reduce the burden of information processing" (Glaser, 1992, p. 248). In summary, the emphasis on conceptual understanding and the diagrammatic representation involved in schema-based instruction might explain the positive results of this study.

It is also encouraging that although both groups seemed to improve their performance on the generalization test after their assigned treatment, the mean increase in score for the SBI group (38.0%) was significantly greater than the mean increase in score for the TI group (10.5%). Specifically, the generalization test consisted of structurally similar but more complex problems (may involve irrelevant information or multi-steps). The finding of this study is supported by precious research (e.g., Jitendra et al., 1998) in that students generalized their learned skills to new tasks. Again, conceptual understanding of the problem structure in conjunction with the diagrammatic representation might have helped students in the SBI group differentiate relevant information from irrelevant data (Schoenfeld and Herrmann, 1982) and correctly solve the generalization problems.

Limitations and Future Research

Overall, the results of this study are encouraging. However, we need to exercise several cautions when generalizing the results of this study. First, the participant sampling procedure in this study did not control for student reading levels. While students' IQ scores are not necessarily highly correlated with students' math word problem solving performance, reading comprehension is an important contributing factor to students' word problem solving performance (e.g., Zenttal & Ferkis, 1993). As such, it is not clear to what extent reading comprehension skills contributed to the findings in this study and vice versa. That is, the extent to which math problem solving strategies that students learned during the intervention helped them improve their reading comprehension skills such as understanding mathematics terms and relations is not clear.

A second limitation of the study is also related to the sampling of participants. Great variations (based on large SDs) in students' pretest performance on both target and transfer problems within each group were noted in this study. That is, both the SBI and TI groups in this study comprised students with diverse levels in terms of math problem solving performance. For instance, student pretest scores for the SBI group ranged from 0.0% to 68.8% correct, and it was the same for the TI group (0.0% to 68.8%). In future research, it would be important to obtain more homogeneous groups and larger size samples to examine possible the differential effects of strategy instruction on the performance of students with different achievement levels. In addition, as noted earlier, the sampling of the normative reference group in this study was volunteer-based. It was not clear whether this group represented the normally achieving group.

A third limitation of this study relates to the "pull-out" instruction that occurred in this study. Specifically, part of this study was conducted during the after school program and part of the study was conducted during the summer school. That is, both programs' instruction did not occur during the regularly scheduled math period in the school. As such, there is a possible disconnect between the strategy instruction provided in this study and the regular classroom instruction. In fact, students reported that they only applied the strategy to other classes "sometimes." Of course, there is an issue pertinent to the application of the strategy to tasks presented in the traditional school curriculum. Nevertheless, it is important for future research to examine the effects of schema-based instruction in regular classroom settings and facilitate students' broad application of the strategy.

Conclusion and Implications

Based on the findings of this study, students who received explicit schematic diagramming strategy instruction outperformed students who received traditional heuristic strategy instruction on both training and transfer problems. Further, they maintained their increased performance three weeks to three months after the completion of the study. The greater effect of the schema-based instruction was also evident in that students in the schema group caught up with and surpassed the performance of the normative reference group after the explicit strategy instruction.

One of the key differences between the schema-based strategy instruction and the traditional general heuristic approach in this study is that only the former emphasizes pattern recognition and schema acquisition by means of problem structure elaboration. The schema-based instruction provided students with explicit instruction of domain-specific knowledge. The schematic diagrams in this study not only helped students in the SBI group to note the underlying problem structure, but also helped them process the information for accurate solution.

For future practice, the school curriculum and classroom instruction should emphasize systematic domain specific knowledge instruction, especially in word problem solving. Based on students' pretest performance in this study, it seems that most students' word problem solving performance was not based on conceptual understanding. They just grabbed all the numbers in the problems and applied an operation to get the answer, regardless of the nature of the problem. Few students drew pictures to represent information given in the problem and then added up their drawings to get the solution. These students attempted to use reasoning and thinking to solve the problems. However, when the numbers in the problem get larger, their drawings and adding may become cumbersome and prone to errors. At other times, the drawings could be confusing and may not work.

In contrast, the schema-based strategy with its emphasis on conceptual understanding facilitated high order thinking for students in this study. Implications for teaching students with relatively low performance using the schema-based strategy may include providing step-by-step explicit instruction in representing and solving the problem. However, for above achieving students, the teacher could facilitate students to generate their own diagrams to represent the problem structure. In both situations, salient features in each problem type should be taught explicitly so that students understand the underlying structure of the problem. At the same time, reasoning and critical thinking should be emphasized during schemata mapping, solution planning, and strategy execution.

As more and more students with diverse needs are served in inclusive classrooms, it is essential to provide students with varied levels of scaffolding support. Deciding how much scaffolding is necessary for students with diverse needs should be based on a careful assessment of students' performance.

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Table 1

Demographic Information of Participants in the Two Comparison Groups

Variable	SBI Group	TI Group	Total
Gender			
Male	5	6	11
Female	6	5	11
Grade			
6^{th}	6	4	10
7^{th}	2	6	8
8^{th}	3	1	4
Mean	6.7	6.7	6.7
Age in months			
Mean (SD)	153.8 (8.6)	156.7 (8.7)	155.3 (8.5)
Ethnicity			
Caucasian	4	3	7
Hispanic	5	7	12
African American	2	1	3
Classification*			
LD	10	8	18
SED	0	1	1
ND	1	2	3

	SBI Group		TI Group		Total	
	Mean (SD)	n	Mean (SD)	n	Mean (SD)	N
IQ**						
Verbal	98 (5.5)	3	93 (5.7)	5	95 (5.9)	8
Performance	93 (2.5)	3	92 (2.1)	5	92 (2.2)	8
Full scale	93 (2.9)	3	92 (3.1)	5	92 (2.9)	8
Math**	24 (6.9)	3	23 (7.3)	5	23 (6.7)	8
Reading**	26 (3.5)	3	31 (5.4)	5	29 (5.1)	8

Note. *LD = Learning disabled; SED = Seriously Emotionally Disturbed; ND = Non-disabled. **Only three students in SBI group and five students in TI group had IQ scores available, and only three in SBI group and five students in TI group had math and reading scores available. IQ scores were obtained from Wechsler Intelligence Scales for Children -Revised. Most students' math and reading scores were from MET (Metropolitan Educational Test), with the exception of one student's achievement scores, which were from SAT9 (Stanford Achievement Test).

Table 2

Sample Word Problems Employed in Pre-, Post-, Maintenance, and Follow-up Tests

Problem Types	Sample Problems
MC*: *Compared unknown*	Sue planted 15 sunflower seeds in her garden last Spring. Emily planted 2/3 as many seeds as Sue. How many seeds did Emily plant?
MC: *Referent unknown*	Vito earned $12 from shoveling snow over the weekend. He earned 1/3 as much as his friend Guy did. How much did Guy earn from shoveling the snow?
MC: *Scalar function unknown*	Sheila has 5 green beads. Sheila has 30 red beads. How many times as many red beads as green beads does Sheila have?
Proportion: *One of the two dimensions unknown*	Mr. Wilson's car can run 30 miles on one gallon of gasoline. He planed to drive 270 miles over the weekend. How many gallons of gasoline will he expect to be used over the weekend?
Proportion: *One of the two dimensions unknown*	A recipe for chocolate cupcakes uses 3 eggs to make 20 cupcakes. If you want to make 80 cupcakes, how many eggs will you need?
Proportion: *Unit value unknown*	Feed for Dolphins costs 30 cents for 12 bags, what would 2 bags cost?

*Note. MC = *Multiplicative compare*

Table 3

Student's Performance on Target Problems Before and After Instruction

	SBI Group			TI Group			Effect Size
	M (%)	N	SD	M (%)	N	SD	
Pretest	25.19	11	22.52	29.85	11	21.36	- 0.21
Posttest	79.41	11	13.92	47.55	11	22.70	+ 1.69
Maintenance	87.29	9	14.51	45.45	11	17.97	+ 2.53
Follow-up	91.68	9	13.79	46.06	10	19.04	+ 2.72

Note. Effect size (ES) was calculated according to the following formula: the SBI group mean minus the TI group mean, and divided by the pooled standard deviation (Hedges & Olkin, 1985); therefore, a positive ES indicates a favorable effect for the SBI, a negative ES indicates a favorable effect for the TI group.

Table 4

Students' Performance on Transfer Problems Before and After Instruction

	SBI Group			TI Group			Effect Size
	M (%)	N	SD	M (%)	N	SD	
Generalization pretest	25.45	11	29.11	35.00	11	22.69	- 0.37
Generalization posttest	62.43	11	21.52	45.50	10	15.89	+ 0.89

Note. Effect size (ES) was calculated according to the following formula: the SBI group mean minus the TI group mean, and divided by the pooled standard deviation (Hedges & Olkin, 1985); therefore, a positive ES indicates a favorable effect for the SBI, a negative ES indicates a favorable effect for the TI group.

Figure Captions

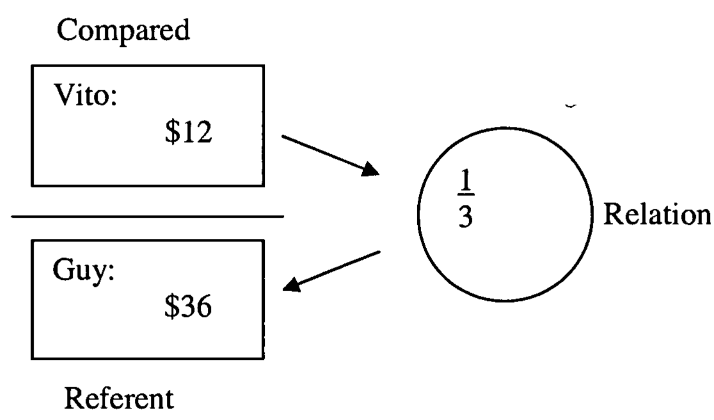
Figure 1. Representation for *multiplicative compare* during problem schemata instruction.

Figure 2. Representation for *proportion* during problem schemata instruction. From Schemas in Problem Solving (p.135) by S. P. Marshall, 1995, New York: Cambridge University Press, Copyright 1995 by Cambridge University Press. Representation adapted.

Figure 3. Two groups' performance on target problems before and after the intervention. Note. 1= pretest. 2 = posttest. 3 = maintenance test. 4 = follow-up test.

Figure 4. Two groups' performance on transfer problems before and after the intervention.

Figure 5. Three group's performance on target problems across time of testing.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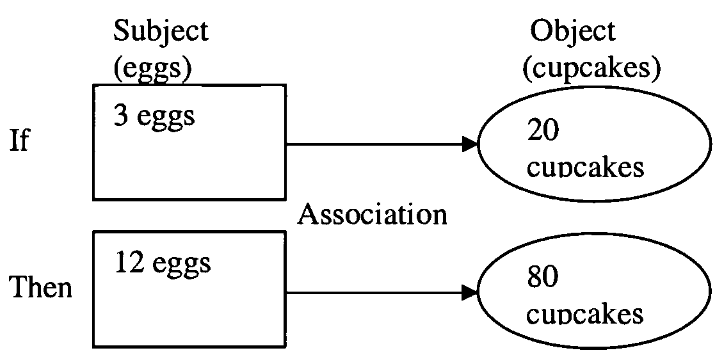
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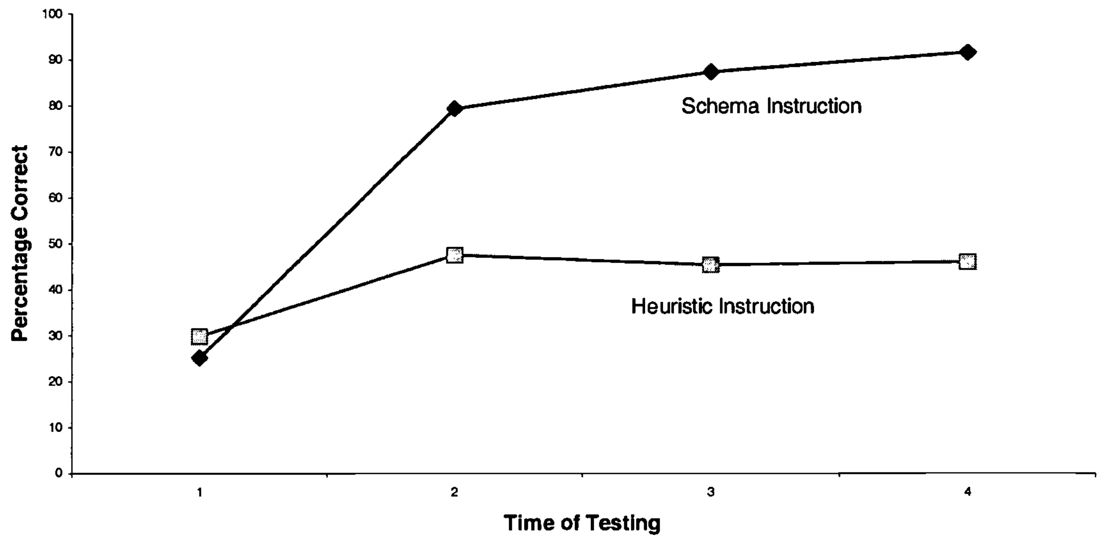
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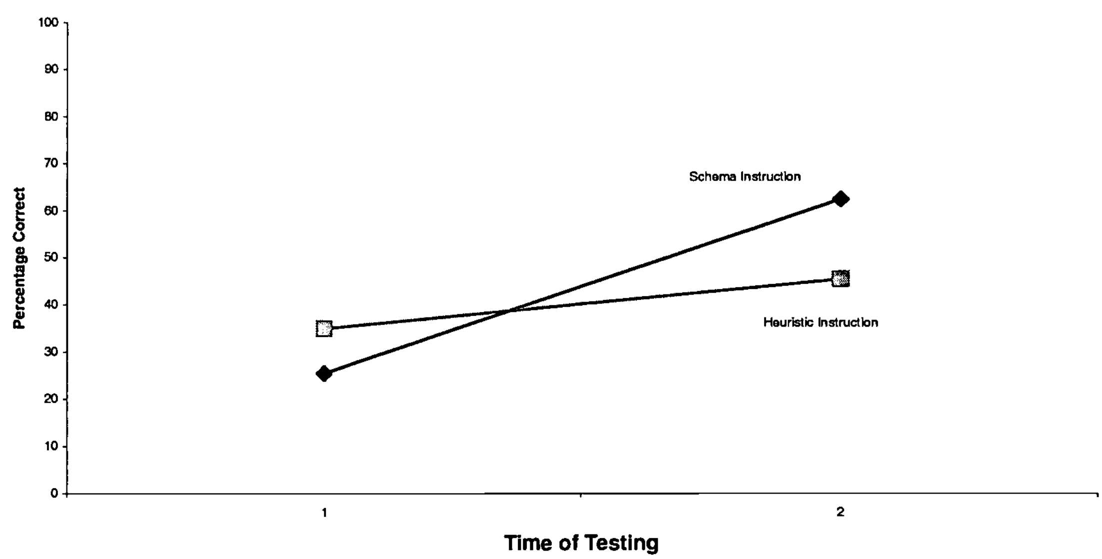
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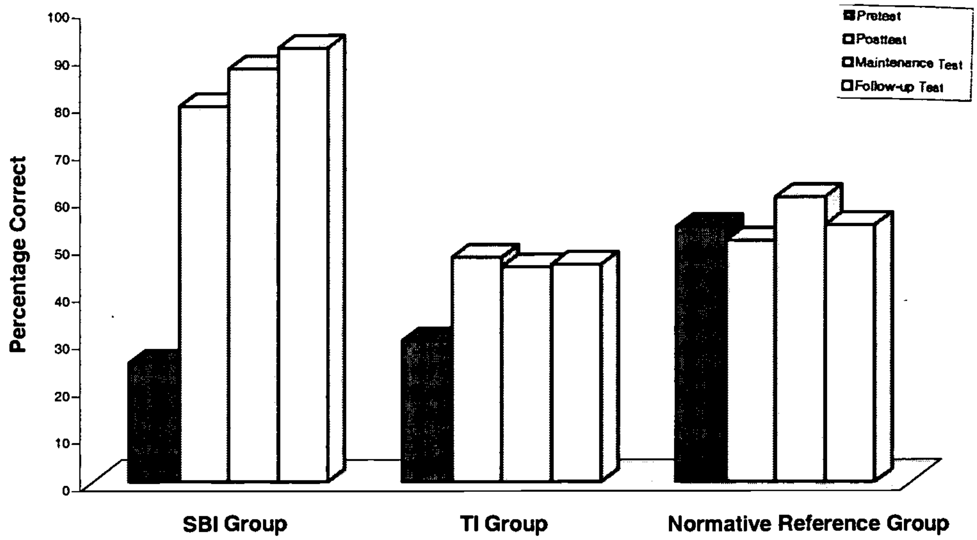
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SBI Group
TI Group
Normative Reference Group

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